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AUTHOR Orvik, James M.; Van Veldhuizen, Philip A.
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ABSTRACT

This study was designed to identify a set of research questions and testable hypothesis to aid in planning long-range research. Five mathematics teachers were selected. These instructors enrolled in a special project-related seminar, video-taped sessions of their own mathematics classes, and kept field journals. The group met once a week to discuss required readings, view video tapes, and relate and discuss examples of classroom episodes and encounters. Hypotheses were developed in: (1) inter-student communication, and (2) the relationship between social events and cognitive change. Researchable questions were also raised as to the relationship between social status and treatment status in classroom interaction. It was also hypothesized that the extent to which students and teachers are willing to pass over breaches of mathematical rules is an indicator of their social motivations to do the work necessary to get schooling accomplished. The investigation focused on three main areas and their interrelationships: (1) the cognitive characteristics of learners and teachers; (2) the nature of mathematical tasks; and (3) teacher/learner social interaction in cross-cultural situations. (Author/MP)

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FINAL REPORT

to

NATIONAL INSTITUTE OF EDUCATION, GRANT NIE-G-80-0092

The Social Basis of Math Teaching and Learning

Submitted
by
James M. Orvik, Ph.D.
Center for Cross-Cultural Studies
and
Philip A. Van Veldhuizen
Department of Mathematics
University of Alaska, Fairbanks
June 24, 1981

U S DEPARTMENT OF HEALTH,
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Abstract

The purpose of the study of the Social Basis of Math Teaching and Learning was to identify a set of research questions and testable hypotheses with respect to which long-range research could be planned. Three main kinds of information were proposed to accomplish this initial task: (1) ethnographic, (2) video tape, and (3) field notes There were three main areas and their interrelationships about which questions would be raised: (1) the cognitive characteristics of learners and teachers; (2) the nature of mathematical tasks; and (3) teacher/learner social interaction in cross-cultural situations.

Five mathematics teachers from the immediate geographical area were selected. These five enrolled in a special project-related seminar, video-taped sessions of their own math classes, and kept field journals. The group met once a week to discuss required readings and to view video tapes and relate and discuss examples of classroom episodes and encounters. Hypotheses were developed in two main areas: 1. inter-student communication, ranging from turn-taking exchanges governed by situational discourse habits, choral responding governed by hypothetical processes of instantaneous communications; 2. the relationship between social events and cognitive change.

Another area in which researchable questions were raised was the relationship between social status, as indicated by significant developmental milestones (e. g., graduation from high school), and treatment status in classroom interaction Finally, it was hypothesized that the extent to which students and teachers are willing to pass over breaches of mathematical rules is an indicator of their social motivations to do the work necessary to get schooling accomplished.

The Social Basis of Math Learning and Teaching
Submitted by: James M. Orvik, Ph.D.

This is the final report of the project funded by the National Institute of Education Grant Number 80-0092. The purpose of the project is to initiate an interdisciplinary research effort onto the role of social factors in teaching and learning mathematics.

During the phase funded by the above grant, a variety of means were to be used to identify a set of research questions and testable hypotheses with respect to which long-range research could be planned. Three main kinds of information were proposed to accomplish this initial task: (1) ethnographic, especially microethnographic; (2) video tape archives; and (3) field notes. There were three main areas and their interrelationships about which questions would be raised: (1) the cognitive characteristics of learners and teachers; (2) the nature of mathematical tasks; and (3) teacher/learner social interaction in cross-cultural situations.

Procedure

Five mathematics teachers from the immediate geographical area were selected to participate in a special topics course (3 credits) entitled "Experimental Seminar in Mathematics Teaching and Learning." The five participants represented the following areas:

(i) public high school - two teachers
(ii) private high school - one teacher
(iii) public junior high school - one teacher
(iv) university remedial algebra I and algebra II course - one teacher

These participants volunteered to video tape their classes for the project archives, making it unnecessary to compose artificial "classrooms" of paid volunteers, as was originally proposed. No attempt was made to select a representative random sample of teachers and students as the goal of the project was to formulate hypotheses rather than test them statistically. These Math teachers represented a wide range of mathematics courses: included were (a) Junior high mathematics (non-algebra), (b) Consumer math (high school), (c) Geometry, (d) Advanced math (senior high), and (e) Remedial math (college students making up academic deficiencies). Appendix A lists the readings that were assigned and discussed in the early part of the seminar. However, as the seminar unfolded, it became increasingly clear that a rigid procedure governed by formal objectives was inappropriate to the kind of seminar participants and was inappropriate to the nature of the task. More of the seminar time became devoted to specific examples of classroom episodes and encounters, and less time to the explanation and discussion of theory, methods, and research findings. It is clear that the initially proposed reading list was often an impediment to the nature of the question-seeking, brainstorming discussion style we came to adopt. The resulting change helped create a no-topic-is-irrelevant atmosphere from which a number of useful

lines of inquiry, discussed below, emerged. The video-taping began during the fourth week of the fall semester, after the necessary clearances, precautions, and provisions for informed consent were enacted.

Two problems were encountered during the course of video-taping. First, the local 1/2" video-tape equipment in each participant's school was incompatible with the 3/4" cassette format used by the investigators. It was decided that all tapes would eventually be dubbed onto 3/4" cassette. This procedure put all tapes into a common format compatible with the playback equipment available to the investigators. An additional advantage of this system is that the resolution degradation is less when dubbing from 1/2" to 3/4" than vice-versa. The 1/2" cassette could be returned for re-use by the participants.

The second major problem encountered was that even with a wide-angle lens, classroom sizes did not generally allow video angles which took in the whole classroom. It was impossible to get the teacher and students in the same picture. It was decided that it is preferable to include the students in the picture and sacrifice seeing the teacher. The teacher nearly always can be heard under these conditions, giving us at least the major verbal events on the teacher's part combined with the visual and verbal (to a point) events characterizing the pupils' behavior. We have thus obtained an analyzable video-tape archive of 14 - 15 classroom hours. Our future plans are to have the participants view these tapes and fill in added information on students and the situations as viewed on the tapes.

In addition to these video-tape archives, a number of audio tapes have been made during the course of the project. One audio tape was made in response to a classroom episode a participant thought remarkable enough to bring to the seminar for discussion. Briefly related, the participant's normally attentive high school geometry class was unusually unresponsive one particular day, causing the teacher to dip especially deeply into his repertoire of teacher skills to seduce, coerce, and cajole the students into academic animation, none of which worked.

After spending the remainder of the seminar session discovering the simple truth that when students don't respond, teachers don't know what to do, the principal investigator volunteered to "interview" the class to get their recollection of what happened on that "day of apathy" as we came to term it. The audio tape we made and subsequently transcribed is a record of the fact that we were about the business of discovering for ourselves what most of the students already knew: that a lot goes on in Math that is far from mathematical. The students, with a minimum of structuring from the interviewer, were not only able to recall the day in question but revealed the existence of other dynamics as well. For instance, most students felt they could "read" their teacher's mood for the day within as few as five seconds. Other students were able to demonstrate precisely how they avoid being called on when they would rather not be. Another student confessed how he knew, by the teacher's behavior, just when it was OK to begin winding down the classroom hour,

usually some ten minutes prior to the bell.

The principal investigator and the teacher/participant, who was also present, both thought the session was valuable for its depth of insight as well as for the enthusiasm the students showed at the time. On the other hand, the students were functionally amnesic about the whole thing within two days. They all acted as if nothing out of the ordinary had occurred at all. Rather than be miffed, the co-investigators simply reaffirmed the virtues of unobtrusive measurement and got on with the project. The remainder of the audio tapes are of various seminar sessions and have not yet been transcribed.

Hypothesis Development

As stated earlier, the goal of the project was to develop questions and hypotheses about social factors in math teaching and learning. As a continuing result of this process, a number of useful questions have been framed and their refinement is now underway.

We have found so far that the most useful areas of inquiry are those that require a continual process of successive approximation and that continually avoid closure. An example of such an area came from observing a college-level "remedial" algebra class. The high school math teachers participating in the seminar were impressed with how quiet the class was. If the students wanted to know something, they just asked. The discussion dwelt on this state of affairs until what was a passing observation was developed into a more elaborate analysis of the relationship between grade level and social systems whereby students literally become eligible for new kinds of treatment as a result of passing milestones such as high school graduation. The most backward college student is apparently eligible to reserve his or her displays of capacity for the test whereas the most advanced junior high school or high school students must be ready during all classroom hours to make public or semi-public displays of their cognitive status. They are not eligible to take their chances on the test.

Consequently, our tentative conceptualization is that there are orderly, though probably nonlinear, changes in treatment status marked by significant social events throughout a person's schooling career, and that these changes of social status are semi-independent of the cognitive changes intended either by the designers of the curriculum or by the teachers.

The unfolding of classroom events can best be understood as a socially controlled process. Timing and sequencing are social skills that must be understood within the context of schooling, and schooling must be understood within the context of society. These are the messages given by practitioners of the ethnomethodological arts such as Erickson (1975) and Mehan (1979). In contrast to the "constitutive"

approach to understanding the nature of classrooms (Mehan, 1979) is what one might call the "trait" approach. We call it the "trait" approach because it formulates prescriptions for the improvement of education on the basis of traits descriptive of the parties to the process. These traits are enduring conditions of the person brought into the situation as skills, attitudes, or personality attributes for which optimum complementarity can be prescribed for efficient learning to take place.

The most recent attempts to improve classroom patterns from the "trait" concept of schooling include suggestions to match students' and teachers' cognitive styles (Messick, 1970; Witkin, Moore, Goodenough, and Cox, 1977). Characteristically, such approaches appeal to an unspecified communication "chemistry" presupposed to exist in the environment of persons who "match" cognitively. Little is said about the role communications among students plays in controlling the nature of that environment. Organizing students and teachers in classroom-sized units creates inevitable processes that ought not to be ignored in research about schooling. During the current project, two lines of inquiry have addressed the process of communications among students as a phenomenon of significant potential importance.

The first line of inquiry arose from the participants' response to what began as a simple group problem-solving exercise. The object was to solve the conundrum, "if he had seen the sawdust, he wouldn't have killed himself," by asking questions that could be answered "yes" or "no."[1] By the following seminar session, three of the participants had tried the exercise in their high school math classes. Each made the similar observations that their consumer math (i. e., least advanced) classes solved the problem much more easily than did their advanced geometry and algebra classes. In fact, one group, the most advanced mathematically, never solved the problem and had to be told the answer.

Observations such as these, because they run counter to conventional wisdom, require further explanation to push them to the brink of intelligibility. In the present case we wondered why students collected into groups on the apparent basis of differential mathematical ability seemed to show a reversal in intellectual advantage on what is obviously a problem calling for the constructive application of (an) intellectual skill(s).

Before speculating further on this anecdote, we introduce another which represents the second line of inquiry on inter-student communication spoken of earlier. While viewing project tapes of a junior high

[1]The problem is solved when the class reconstructs an intelligible account of the cryptic information given. The relevant facts in this case are that the subject is a blind midget in a circus, driven to suicide by another midget who wants the first midget's job. The pretender's deed is effected by means of surreptitiously sawing off bits of the blind victim's cane who performs his sad despatch in anguish over "growing" too tall for his work.

school math class, we began to focus on instances of choral responding to teacher-initiated directives. These instances represent a species of behavioral events endemic to some, though by no means all, classrooms. Their probability of occurrence most certainly varies from teacher to teacher, subject to subject, and grade to grade. The latter variation is taken up as a topic in its own right in another section of this report.

Our interest presently is in the functions served by such behavior. For example, as a means of social control, choral responding reinforces the eligibility of the teacher to command such behavior from the students.[2] As a form of inter-student communication, however, social functions may be served whose cognitive implications are far-reaching. One thing that may be reinforced by choral responding is a sense of mutual interdependence in the learning process among students.

In order to establish any relevant social functions of choral responding in math, or any other classrooms, it must first be demonstrated that the individual responses are not independent. That is, it must be shown that how or when one student responds influences how or when another student responds. Given the short pause time usually prevailing between when a teacher asks a question and if no reply is forthcoming, nonindependence in a choral response would imply the existence of communication not previously investigated. Rowe (1974a) reports an average pause time of about one second, in her analysis of primary science classrooms, for questions directed toward individual pupils. Our preliminary observations are that the pause dynamics for choral responding require a much different conceptualization.

More important, for the present discussion however, is the possibility that choral responding contains within it forms of inter-student communication that can best be termed "instantaneous" in that the latencies between responses among individuals are too small to be accounted for by reaction time alone. To the extent instantaneous communication can be shown to be part of choral responding, its importance as a topic of inquiry is established. Two questions are immediately relevant in this regard. What learning function does it serve, and what sort of individual variation is there in the tendency to employ it?

In the foregoing, we have singled out two kinds of social interaction in the classroom worth investigating: individual question and answer, and simultaneous choral. The first is at a discourse level we

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[2]We have yet to record an instance of students prompting demand responses from the teachers, at least not of the variety in which teachers are required to display the status of their cognitive development. An apparent exception to this asymmetrical authority relationship is illustrated by Mehan (1979), in cases where students act as teachers for their peers. That they indeed do act just like teachers in adopting the ubiquitous "initiation-reply-evaluation" sequence is proof enough that both parties understand their roles quite well.

find familiar because it represents a use of discourse rooted firmly in day-to-day social intercourse; asking questions to find things out. What is surprising. and therefore worth investigating further, is the observation that the ability to profit by its use may often reside in those deemed less advantaged intellectually. What we think may be happening is that the organization of students on one ability, to take advantage of their special (math) skills, inadvertently organizes them in other ways as well. The problem is that the ignored patterns of ability (e. g., social) do not, by definition, get transformed into useful modes of teaching except by accident. The investigation of this kind of inter-student communication would be to: (a) substantiate formally the informal observation of the apparent advantage reversal, and (b) to establish the extent to which this kind of interaction can be tailored to the interaction style, not of the individual student, but of the classes into which they are organized. What may be happening is an interaction between student characteristics and the classroom environment such that previously ignored social orientations can be capitalized upon by reorganizing the classroom interaction to increase the probability of verbal sharing and prompting among students.

The hypothetical existence of instantaneous communication is an area of investigation somewhat more complex, mainly because of the micro-analytic methods necessary for its substantiation. However, once substantiated, questions about the function of this form of communication could then be raised. For the present discussion, instantaneous communication would represent the hypothetically minimum conditions necessary for students to influence each other's behavior in a socially meaningful, perhaps even cognitive, way.

Methods are being considered for investigating the existence of instantaneous communication. The co-investigators believe that the technical means exist to record and display individual student responses during choral episodes to determine their degree of independence as a function of systematic deviations from normally distributed audio amplitudes over time. The contribution of individual students to the group audio record could be studied further by a multi-channel recording of individual students within a group, ramdomly sampled and supplied with individual lavalier microphones synchronized with the master sound distribution. Thus, two kinds of events are conceived as happening simultaneously; the cumulative group response whose variance is simply the total of the individuals responding independently and those responses contingent on the responses of others in the group.

These two kinds of inter-student communication also imply a wider variety of social influences in the classroom than at first glance might be perceived. At the very least, they serve as a strong reminder that cognitive business is not the sole business of the math classroom. More precisely put, the cognitive business of math classrooms is conducted through the means of social interaction.

In its broader sense, discourse and its prevailing rules constitute the social interaction by which classroom work is managed. What we are concerned with, in fact, is the relationship between culturally governed discourse habits and the resulting cognitive changes that are intended to take place in the students. By discourse habits we mean the totality of learnable verbal and paraverbal behaviors that constitute standard-operating-procedure in face-to-face interaction. In classrooms, as in any situation, standard-operating-procedure is a combination of the habits people bring into the situation and the adaptations negotiated to fit the particular players and the particular context.

One important aspect of the standard-operating-procedures under which discourse habits are enacted is that the actors are seldom aware of their ruling influence. Another important aspect is that those habits and procedures are not easily modified, not so much because people are stubborn, but because the ability for people to make sense to each other requires them not to deviate beyond certain limits of enactable behaviors.

Among the discourse habits relevant to research about teaching is the management of pauses by teachers and pupils in classroom interaction. Research by Rowe (1974a, b) was noted earlier in conjunction with our ideas about inter-student communication. Rowe's research, however, was directed to teacher pauses, sequences of interaction between teachers and students but nonetheless illustrates both the pervasiveness and robustness of the one-second average pause time between primary science teachers' questions and their retrieval of control if students do not respond. When teachers were trained to increase their average pause time to three to five seconds, significant changes took place both in the students' responses and in the teachers' behavior.

For students, the most important changes were to increase the length of their responses, show more confidence, and respond with more variety, all of which led to a more equitable distribution of the amount of "floor time" for getting cognitive business accomplished. Teachers increased the flexibility of their responses, and to some extent raised their expectations of pupils previously rated as "slow."

The potential for profound restructuring of the social interactions between student and teacher to take place by breaking this one small discourse habit was illustrated by an incident brought out during one of our seminar sessions. A high school student became animatedly frustrated with her math teacher. The teacher's main clue to the existence of frustration came when the student stormed out of the room saying, "You're the worst f_ _ _ _ n' g_ _ _ _m' teacher I ever had!" Two days later the teacher and student tried the math problem again, this time under calmer conditions. During the course of explanation, at a juncture determined by the student, the teacher was ordered to "wait a minute" while the student absorbed the problem up to that point at which time the student said, "OK" and they continued this cycle until the entire problem was successfully comprehended.

Three points emerged from what at first glance seems to be an inocuous anecdote. First of all, the management of the teacher's pauses, when they occurred and for how long, were forcefully controlled by the student, with significant cognitive results. Second, in recounting the tale, the teacher didn't seem to consider the reversal of control of anything more than incidental importance. Third, all of the adaptations made by the two parties are well within the bounds of intelligible behavior. That is, nothing bizarre happened, even though some low probability events took place.

One implication of this incident is that not just any restructuring of discourse habits will do. It has to be (a) within the bounds of intelligible social interaction and (b) useful in meeting some cognitive end. We assume, for example, that teachers in Rowe's research met the first criterion by maintaining a synchronized response style while increasing their pause time. They didn't just increase to three seconds and then interrupt students come what may: Only if normal behavior replaced normal behavior could there have been a successful experiment.

Regarding the second criterion, we have good reason to believe that the extra time given allows not merely more mental computation time, but a whole host of mental routines to be executed. Sternberg (1979) has put forth a theory of mental abilities that offers some important clues as to what goes on during problem-solving relevant to the cognitive importance of increased pause time. Sternberg uses an information-processing approach in which problems are "decomposed" into parts presumed to conform to the different information-processing components used to work on them.

> A component is an elementary information process that operates on internal representations of objects or symbols. (p. 221)

Five information processes are theorized by Sternberg as critical to solving tasks such as those encountered in syllogisms and verbal analogies. These processes are: encoding, inference, application, justification, and response. For a student, in order to answer a question, the question must first be encoded into internal objects and symbols to which the information process can be applied. The student must then operate on these internal objects and symbols by inferring properties and relationships that must be part of the problem. These properties and relationships may then be applied to the encoded objects in solution to the problem, followed by a justification of a solution as the best, most likely, or least incorrect. Finally, the student must then encode the fruits of these cognitive labors into terms acceptable to the public, i. e., that qualify as meaningful utterances, and then respond.

Sternberg has found considerable individual variation in the length of time required by subjects for executing each of the many components needed to solve even the simplest verbal problem. What the student of

the above anecdote did in real life crudely is what Sternberg does in the laboratory elegantly. That is, they both decomposed complex tasks into component parts conforming to the information processes used by particular brains to go about solving them.

It is our hypothesis that the restructuring of social (discourse) events, such as those pointed out by Rowe, leads to useful cognitive change (a) when they stay within the bounds of familiar discourse, and (b) to the extent they allow individuals to control the flow of problem and answer presentations.

We close this section of the narrative with one additional illustration of the critical nature of social factors in the constitution of math classrooms. This example points out some of the circumstances under which both students and teachers can ignore deviations from established mathematical rules in order to maintain the momentum of the unfolding enactment of classroom business.

The episode came from a junior high school classroom tape showing at least two times within a ten-minute interval, the teacher clearly reinforcing that it is wrong to leave a fraction in improper form. On both occasions, the students responded appropriately by acknowledging their oversight and either correcting themselves or accepting the corrections of other students.

Within two days, during a lesson on the division of fractions, the teacher several times left fractions in technically[3] improper form. The students neither corrected the teacher, which is not surprising, nor showed confusion; also not surprising. We can conclude from this episode that the reduction of fractions to proper form is either (a) an optional rule of ettiquette, or one that does not apply symetrically to students and teachers alike, or (b) a rule whose observance is contingent upon whether to do so would seriously interfere with the smooth unfolding of classroom events. There are alternative explanations, of course, but the ones we are interested in are those that allow us to distinguish between social requirements and cognitive requirements.

Clearly, the ability of the teachers to communicate the main features of fractions and the students' ability to comprehend them do not require strict observance of all technical aspects at all times. Furthermore, there is an independent logic, perhaps a psycho-logic or socio-logic operating by which intelligent functioning in the group gets organized and managed in order to get a functionally adequate level of understanding accomplished. The functional adequacy of the resulting understanding is itself socially defined, partly within the situation and partly without.

The foregoing demonstrates quite vividly the tacit negotiations

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[3] We use "technically" here, as opposed to "morally."

implicit in classroom learning devoted to the setting of performance standards. Our work so far has allowed us to penetrate at least the top layer of a social structure based on what seem like self-planned conspiracies under which people find out how students and teachers act and then act that way.

Dissemination

The dissemination of the project findings is now underway. In addition to informal discussions with local colleagues, we were able to share some of our materials with Dr. Fred Erickson of the Institute for Research and Teaching, Michigan State University. A formal paper was presented at the annual meeting of the Alaska Behavioral Science Conference on April 11, 1981. We have a tentative invitation to present a paper on our hypotheses at the National Council of Teachers of Mathematics meeting in Pocatello, Idaho in March of 1982. We also plan to submit articles to journals such as The Mathematics Teacher.

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Robin McDougall, Math teacher, Tanana Valley Junior High School, Fairbanks, Alaska
Lee Solis, Math teacher, West Valley High School, Fairbanks, Alaska
Leroy Wenstrom, Math teacher, West Valley High School. Fairbanks, Alaska
Nan Cockburn Worum, Graduate Student, Remedial Math Instructor University of Alaska, Fairbanks, Alaska
as research collaborators.

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